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ABSTRACT

This paper examines what it would take to expand the number of teacher leaders in mathematics, noting that one of the major obstacles facing reform in mathematics education is the lack of adequate preparation among teachers currently teaching mathematics. The paper highlights experiences that have promoted the development of three middle school mathematics teacher leaders. First, it describes the professional journey of an exceptional teacher leader with 40 years of experience in diverse school environments. Next, it examines the training of two others who are still emerging as teacher leaders. The stories underscore the reality that efforts to promote improvements in mathematics education programs will not succeed unless they are coupled with opportunities that target teachers' need to grow as professionals. All three teachers share a strong commitment to raising the level of student mathematics achievement, making personal changes and improvements to positively affect their teaching quality. All three work to evaluate their teaching and strengthen their weaknesses. Two of the teacher leaders realized that they did not know enough math to truly engage their students in meaningful mathematics discourse. The results emphasize the need for support from district leadership and continuous professional development. (Contains 11 references.) (SM)

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The Special Case of Mathematics: Insufficient Content Knowledge a Major Obstacle to Reform

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The Special Case of Mathematics: Insufficient Content Knowledge a Major Obstacle to Reform

Introduction

Mathematics education has been at the center of the national interest for the past two decades for various reasons. For one, the data from international tests consistently indicate that American students perform lower in mathematics compared to students in many other, often less economically-developed, nations (e.g., National Center for Education Statistics, 1999). It has also been noted that the numbers of students in this country pursuing degrees in science and engineering is steadily declining (National Science Board, 1999). The implication is that, if left unchecked, this downward trend could impact the position of the United States as an economic power.

To address these problems of national magnitude, initiatives designed to improve mathematics teaching and learning have been put in place in district and states throughout the country. Reform strategies have focused on the development of high standards and related assessment and curricular materials. Yet, while there is no question that these efforts are necessary, there is little evidence supporting the effectiveness of any of these tools in promoting changes in teaching practices. It is becoming increasingly evident that what is needed to raise the mathematical performance of American students is improving the quality of teaching in our schools (Stigler & Hiebert, 1999).

One way to improve mathematics instruction is to focus reform efforts on the on-going training of teachers. Teachers can and do make a difference in student learning (The Education Trust, 1998); therefore, it makes sense to ensure they are adequately prepared to teach mathematics. After all, teachers get blamed for students failing, so why not recognize them as the critical variable in improving mathematics education.

Studies conducted in classrooms where students perform at high levels and learn challenging mathematics suggests that teacher knowledge of mathematical content is a key factor that underlies the quality of classroom instruction (e.g., Ma, 1999; The Education Trust, 1998). Teachers who possess a deep and broad understanding of fundamental mathematics provide more rigorous instruction for their students, which in turn, leads to higher student achievement in mathematics. The implication from such results is that professional development should be geared toward promoting teachers' subject matter knowledge.

In order for teachers in the field to acquire the greater mathematical understanding needed to align their instructional practice with reform goals they must be supported in their efforts. Clearly, it is important that district and school administrators actively lead and support the implementation of new policies. In reality, however, few administrators have the time and/or mathematical expertise required to serve effectively as instructional leaders. Well-qualified classroom teachers can provide much needed resource assistance by supporting changes in teaching practices at the classroom level. Teacher leaders can provide guidance by formulating a vision, directing initiatives that lead to improvements in mathematics education, serving as school-based expert consultants,

and offering feedback and encouragement to colleagues as they try new approaches. To put it succinctly, these teacher can be "agents of change" leading reform.

In middle school mathematics teacher leaders appear to be a scarce commodity. Early in the teacher leader study finding mathematics teachers who qualified for the study proved to be a major challenge. The criteria we established were that participants had to work in urban schools engaged in standards-based reform and exhibit a deep understanding of their discipline and related standards. In addition, they had to demonstrate an ability to translate standards into effective classroom practices, and be involved with actively supporting colleagues in this process. Inquiries with district administrators were repeatedly answered with a frustrated reply that they could not think of any middle school math teachers who met the criteria we'd established. We became keenly aware of the point noted by Stigler and Hiebert (1999) that, "one of the biggest problems schools face is that there are few leaders among its teachers for launching" and leading needed reform efforts.

Undoubtedly this shortage of teacher leaders is impacted by insufficient content knowledge among our nation's middle school teachers of mathematics (Ingersoll, 1999). In the various urban school districts we have been involved, we have found that few middle school teachers have majors or even minors in mathematics as a foundation. But, even an undergraduate education in mathematics may not be enough because courses taken toward a mathematics degree don't necessarily promote the pedagogical content knowledge (i.e., deep conceptual understanding or longitudinal development of important mathematical ideas) needed to teach the level of mathematics called for by district, state, and national standards.

The lack of teacher leaders in mathematics has clear implications for the success of reform efforts. Unless we develop a critical mass of such change agents, widespread and lasting improvements in the teaching of mathematics are not likely to happen. What would it take, therefore, to expand the number of teacher leaders in mathematics? To help answer this question, we examine the experiences that have promoted the development of three middle school mathematics teacher leaders. First, we look in detail at the professional journey of an exceptional teacher leader. Then we examine the training of two others, who are still emerging as teacher leaders. The purpose, however, is not to make comparisons between the caliber of the teacher leaders. Rather, the goal is to use their stories to illustrate the issues for policymakers, administrators and practitioners about the sorts of professional development activities needed to nurture the transformation of a mathematics teacher into an effective classroom teacher and teacher leader.

Rachel: The Story of an Outstanding Teacher Leader

Rachel is a middle school teacher with 40 years of experience in diverse school environments. Although currently engaged as a teacher of mathematics, Rachel was initially trained as a Language Arts teacher. It is not her longevity as a teacher or her preparation that accounts for her exemplary performance as a leader in mathematics reform. Actually, the story behind Rachel's transformation into a teacher leader can be understood by looking at her experiences in the last ten years of her long teaching career.

In 1990, Rachel was recruited by a principal to teach mathematics in a middle school in a largely Hispanic district. Rachel shared this administrator's determination to raise the academic performance of students at the school. To achieve this goal, and with the encouragement and support of the principal, Rachel became involved in a number of professional-development opportunities that she felt were responsible for transforming her into the teacher leader she is today. It is important to point out that Rachel's initial steps into leadership roles were spurred by another leader; in this case, a school administrator. By encouraging excellent teachers to take a more active role in reform efforts mentors can play a significant role in fostering teacher leadership. This driving force could come from many sources including another teacher leader, a school or district administrator, or even a national organization. Rachel's path to leadership began with a principal that was driven, like her, to make a difference.

Rachel's principal worked with a team of teachers to secure several grants made available to low-income schools in the state. The goal of these grants was to improve student learning by concentrating the efforts of teams of teachers on the alignment between assessment and instruction and the state frameworks. Funding from these grants provided numerous professional opportunities and time to collaborate with colleagues. Over the course of several years, Rachel and her colleagues were transformed into a community of reflective teachers who valued and used open-ended questions, scoring rubrics, portfolios, and student peer assessment. In addition, through the collaborative nature of their work, Rachel and the teachers at her school developed a shared understanding of what quality work looks like. These experiences led to changes in Rachel's teaching practices. The grants also provided Rachel with opportunities to develop other professional skills as she played significant leadership roles on both the English and mathematics teams at her school.

At the recommendation of her principal, Rachel became involved with Classroom Assessment in Mathematics (CAM), a National Science Foundation (NSF) funded project. The CAM project gave Rachel opportunities to grow in various ways as a teacher and a leader. For one, it expanded her professional network as the project required that Rachel work in collaboration with teachers from other school districts and interact with representatives from state and national organizations such as the National Council of Teachers of Mathematics (NCTM). Through contact with this broader network, Rachel felt empowered by colleagues who shared her belief that they could make a difference. Through participation in project workshops Rachel developed a better understanding of the utility of reflection and open-ended questioning strategies as tools for assessing students. In addition, as part of her involvement in the CAM, Rachel became a site facilitator for the pilot test of Connected Mathematics Project (CMP), an integrated middle school mathematics curriculum. Rachel credits CMP with furthering her understanding of fundamental mathematical concepts, and helping her comprehend the longitudinal development and coherence of mathematical knowledge.

Rachel ascribes the Assessment Communities of Teachers (ACT), another NSF-funded project that was a follow-up to the CAM project, for having the greatest impact on her transformation into a teacher leader. ACT was a teacher-leader development project that promoted the use of assessment to drive instructional change. Through ACT, Rachel's expertise regarding curriculum and its alignment with assessment was substantially enhanced. Of greater significance, however, the project provided Rachel with the type of comprehensive leadership training she needed to become effective as a leader. Rachel was introduced to CBAM, or Concerns-Based Adoption Model

(Loucks-Horsley & Stiegelbauer, 1991), that explains the phases of the change process as delineated by progressive levels of concern. She learned how to understand individual teacher's concerns and how to use the CBAM framework to guide staff development. The leadership training helped Rachel learn to use effective communication skills as tools to work skillfully with teachers who hold views that stand in the way of transforming their teaching. Rachel also learned about the notion of a learning organization (Senge, 1990) which helped her grasp the culture of schooling, and the contributions that teacher leaders can make to effect changes in school cultures.

But, even more important than the leadership skills she learned, participation in the ACT and CAM enterprises made Rachel keenly aware that her subject matter knowledge of mathematics limited her ability to teach effectively. As she acquired expertise in the use of problem solving and questioning strategies to challenge students, Rachel found that she lacked the mathematical competence needed to pose conceptually demanding problems and questions and lead discussions. As she learned about a range of assessment approaches, Rachel noted the restrictions that limited content knowledge places on a teacher's ability to analyze student responses for misconceptions and gaps in student understanding. These realizations prompted Rachel to actively pursue opportunities to develop her own content knowledge by participating in workshops and attending conferences sponsored by the NCTM.

Over time, Rachel credits her active participation with colleagues in the ACT and CAM training sessions with promoting growth in her teaching expertise and contributing to the development of her mathematical knowledge. Many of the program's workshops included opportunities to study, to do and to discuss mathematics; to try out and evaluate videotaped lessons; and to reflect on these activities. Through these "hands-on" collaborative forums, Rachel learned new mathematics, developed new ways to teach mathematics by engaging students in problem solving, and found the collegial support needed to implement the changes she made in her teaching.

In looking back Rachel feels that the ACT and CAM projects were the "best thing that every happened to [her]." Furthermore, she observes that many of her colleagues have participated in extensive staff development in mathematics, but none have had an experience equal to hers. For the most part their experiences have consisted of a few one-day sessions designed as introductions to new instructional techniques or topics in the curriculum. The uniqueness of Rachel's experience addresses a central concern in middle school mathematics. Research reveals that too few teachers experience the depth and quality of on-going professional development that Rachel enjoyed (Cohen & Hill, 1998). This may explain why we encountered such a scarcity of teacher leaders in urban middle school mathematics.

Rachel's transformation into a teacher leader was built upon a series of professional development experiences composed of all the elements Stigler and Hiebert (1999) identified in their analysis of videotapes from the Third International Math and Science Study (TIMSS) that accounted for quality of Japanese teachers' teaching. First, Rachel's learning occurred over a ten-year period, with consistent practice, reinforcement, and examination of her teaching. Second, all of the training maintained a focus on student learning: the questioning strategies, the use of student work to analyze and assess student learning, and an emphasis on developing understanding of important mathematical ideas. Third, whether the objective was teaching skills or leadership skills, Rachel and her colleagues targeted improving practices in the context in which they would be used.

Fourth, all the training was collaborative. Teachers in these projects learned and practiced with the support of skilled facilitators and committed colleagues. Finally, the projects prompted teachers into the role of agents of change. While participating teachers were growing professionally, they were also contributing to the learning and advancement of their colleagues outside of the project. As Stigler and Hiebert contend, it is this type of rich, comprehensive, and reflective learning environment that is needed to help teachers develop the deeper and broader capabilities needed to improve their teaching.

There is no question that Rachel exemplifies the kind of teacher leader that is needed to revolutionize the teaching of school mathematics. She is highly respected by her colleagues and administrators for her leadership capabilities. The list of leadership duties she has taken on relative to middle school mathematics is quite impressive. Among other roles, Rachel has served as department chair, vice president of a regional math collaborative, mentor teacher, grant coordinator, chair of a range of school, district and state committees, and conference presenter. Rachel has also received recognition for her teaching expertise. Her ability to orchestrate student learning within a setting that combines challenging mathematics, problem solving, conceptual connections and communication skills has not gone unnoticed. Her teaching performance has been highlighted in videotapes produced by organizations leading mathematics reform.

In our search for mathematics teachers we found that most who were functioning as teacher leaders were in the process of developing into the caliber of teacher leader exemplified by Rachel. We now turn to the stories of two such middle-school math teachers who have taken on significant leadership roles. As one might expect, their experiences have been quite different from that of Rachel.

Amber, Content Knowledge is Only One Piece of the Puzzle

Amber is a middle school mathematics teacher with 14 years of experience. Of all the mathematics teacher leaders we studied, Amber was the only one who has an undergraduate degree in mathematics. With this educational background, we knew that Amber had acquired the type of solid subject matter knowledge desirable in a teacher of mathematics. Despite this content expertise, Amber's story reveals that teacher leaders need considerable broad-based support to develop the skills needed to be effective teachers.

In her school district, Amber is viewed as a teacher leader. She acquired her first insights into the direction of math reform while a student in a methods course required as part of her credential program. This course helped Amber comprehend the importance of problem solving in math education. Subsequently, as a practicing teacher, Amber actively participated in the regional division of the NCTM, and became involved in a number of state and district standards and assessment development committees. Her commitment to professional development in mathematics is evidenced by the numerous workshops she has attended and conducted. Amber credits one workshop, Math in the Mind's Eye (reference), or Visual Math, as being one of her most significant professional development experiences. It enriched her own understanding of math, and helped her see the value of visual representations in promoting student understanding. As a presenter, she recently led a workshop that focused on questioning strategies, and was designed to get teachers to use problem solving in their classrooms.

In essence, Amber stands out in her district because she participates and is active. She understands conceptually the goals of math reform, and what needs to happen to improve her teaching as well as to support other teachers in reforming their practices. Amber's strong commitment is evidenced by her determination to procure what she needs. For example, aware of her difficulties controlling her students, Amber sat in the classroom of another teacher for three weeks to observe and learn new management strategies. As Amber readily admits, "I've made it my business to find out what was available out there, what's going on, how math was changing, and [looked for] ideas about how to change things."

But, while Amber is cognizant of what is needed, classroom observations reveal that she has not substantially changed her practice. For the most part, Amber is a traditional mathematics teacher who is most comfortable in a well-controlled, teacher-directed environment. Essentially, a lesson consists of going over homework, presenting new material, and giving students time to practice. Amber rarely carries out investigations and group projects with her students because she is concerned with loosing control. She also doesn't invite discussions because she doesn't feel comfortable orchestrating open exploration and discourse. Despite her content expertise, Amber lacks confidence in her ability to handle spontaneity in student comments during discussions.

Amber's inability to break from established teaching patterns can, to some extent, be attributed to a lack of administrative or collegial support. Amber teaches in a district in which standards reform has yet to take hold. Colleagues in her department are still learning about the NCTM recommendations for more rigorous instruction. Teachers in Amber's school are only beginning to experiment with new approaches to teaching mathematics. Unless Amber's district and colleagues change along with her, Amber is not likely to make much headway in her efforts to reform her practice.

Clearly some of the key elements needed to support change in Amber's teaching are in place and others are not. Nevertheless, it is important to note some changes that have taken place in Amber's practice. For example, as a department, Amber and her colleagues recently introduced writing into the math curriculum by asking students to explain their thinking and problem-solving strategies. Amber became involved in a school-wide effort to use assessment information to identify strengths and weaknesses in student performance, an activity that led her to understand the value of looking at student work. In her classroom, she now makes sure students know what is expected of them and how they will be evaluated. Amber expanded her scoring approaches to incorporate rubrics because they facilitated providing feedback to students about their performance.

With these small steps, and equipped with the knowledge she has, Amber has much to offer her colleagues who are just learning about standards reform and want to make changes in their teaching. Once Amber is on the road to reforming her own teaching, it will be easier for her to effect changes in others. Making these changes will give her the confidence and credibility needed to implement the type of instructional leadership reflective of an effective teacher leader.

It is evident that Amber has not had opportunities to establish the type of ongoing collaborative learning community that Rachel developed through her professional development experience. Amber has attempted to implement changes on her own in the isolation of her classroom. Although

expensive and difficult to bring about, Amber would benefit from professional development that includes opportunities to share information and establish networks. For a teacher who is still concerned about her ability to manage classroom activities, attempting to innovate without mentoring or collegial support still feels too risky.

Vickie[1], The Process of Evolving from a Math Phobic to a Teacher Leader

Although always interested in education, Vickie did not become a teacher until later in life after her youngest child graduated from high school. Vickie is currently in her fourth year teaching math in an ethnically diverse middle school of one of the nation's largest urban school districts. In her second year teaching, Vickie accepted the responsibility of heading up the mathematics department at her school. This is a role she initially took on because none of the other mathematics teachers at her school were willing to do it. However, after noting Vickie's commitment and evolving leadership abilities, her principal and colleagues successfully beseeched her to continue in her position as department head.

Vickie's desire to become a teacher was an easy extension of her the nurturing abilities she felt came natural to her in her role as a parent. Vickie loves children and, like Rachel, shares the strong desire to make a contribution to their lives. Vickie's commitment to education is evident in all aspects of her teaching, from the efforts she puts into planning lessons, the enthusiasm and warmth she exhibits toward mathematics and her students, and the determination she has shown to improve herself as a teacher and leader.

By all accounts Vickie is a dynamic teacher who encourages her students to take control of their learning. Her classroom is an environment where students feel comfortable taking risks, and are able to interact with each other in a respectful and productive manner. While Vickie does provide come opportunities for students to collaborate and engage in discussions, she admits to using didactic teaching approaches more often than not. Furthermore, Vickie presents her students with challenging problems and targets conceptually important ideas in her instruction (e.g., the relationships between different representations for rational numbers), yet Vickie's lessons lack the coherence and flow that would support more successful learning.

Despite recently going through a teacher education program and her ability to manage her classroom and lead her colleagues, Vickie strongly feels that her effectiveness as a math teacher and department head is impacted mainly by her lack of content knowledge. She actually describes herself as growing up "math phobic." So fearful was Vickie of mathematics that her initial teaching goal was to become an elementary school teacher because she was convinced that this way she could avoid math courses altogether. It wasn't long, however, before Vickie ended up in a remedial math class where a remarkable college professor inspired Vickie into developing a

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[1]It is important to note that Vickie is not one of the participants in the teacher leader study. We learned about Vickie through another project, and included her experiences in this paper because she comes from a large urban district committed to standards reform, and is not unlike many teacher leaders we encounter in our interactions with urban middle schools. Vickie is a department chair, has limited teaching experience, and struggles to get access to content focused training.

passion for mathematics. In fact, shortly before graduating, Vickie found that she had accumulated enough units in math to qualify to teach math at the middle level.

In her first year of teaching and in spite the math courses and teacher preparation classes, Vickie discovered that her undergraduate education had failed to adequately prepare her for teaching mathematics. She felt there were serious gaps in her subject matter competence that restricted her ability to teach effectively. The weakness in Vickie's content knowledge was confirmed by her failure to pass the mathematics test that constituted the subject matter component of the Professional Teacher Certification test.

To get access to the knowledge she felt she needed, Vickie discovered she had to go outside of her school district. She participated in two mathematics projects at local universities designed to promote teacher's subject matter knowledge in several topic areas. In her relatively short teaching career she also has found time to attend several math conferences and workshops sponsored by her state's math council. While each of these opportunities has contributed to some growth in subject matter knowledge, Vickie still feels her command of instructional strategies is limited, and doesn't yet have a handle on what she calls the "the big picture" in mathematics. That is, Vickie is still missing a clear understanding of the conceptual organization of mathematics. She has been unable to get access to the type of professional development opportunities that would help her understand the relationships among important ideas; comprehend the developmental sequence of mathematical understanding; and equip her with a repertoire of approaches for effectively teaching fundamental skills and deep understanding of important concepts.

Vicki is highly motivated, but is frustrated by her limitations and the lack of appropriate support offered by her district and the lack of time available to think about and plan what she is to teach. This frustration is further compounded by the recent implementation of rigorous content standards in the school district where she teaches, and the call for teachers to teach to the standards and not rely on textbooks as the sole source of mathematics lessons.

In her role as a department leader, Vickie knows that she is expected to be able to lead and support her colleagues in planning and delivering quality standards-based instruction. To provide the type of leadership needed to reform the teaching practices of the other teachers in her department, Vickie knows she needs to target the shortcomings in her own content and pedagogical training. She needs to develop her knowledge of mathematics, expand her teaching strategies, and be prepared to use alternative assessments.

Vickie also observes that while she may not be adequately prepared to provide quality mathematics instruction, she is still better prepared than the other members of her department. So as a leader intent on making a difference, she encourages her department colleagues to collaborate to find and evaluate alternative approaches for improving student learning. This way her efforts to improve her own teaching will not happen in isolation, a factor that she feels enhances the likelihood of her success as well as that of her colleagues in becoming a better teacher.

Not unlike many teachers who find themselves thrust into leadership roles, Vickie is an inexperienced teacher. Despite her short career, Vickie has already had experiences that have led her to the realization that she doesn't have the subject matter expertise she needs to be an effective

teacher. She knows that content knowledge is the foundation upon which teacher leaders build credibility. Vickie also lacks access to significant support from a mentor or from like-minded colleagues at her school site. Nevertheless, Vickie is intent on stimulating changes among her math department teachers. Although this shows real tenacity on Vickie's part, without someone to nurture her leadership it seems likely that Vickie will eventually become frustrated and burn out.

What have we learned from the professional journeys of these three teachers?
As stated in the introduction, one of the major obstacles facing reform in math education is the lack of adequate preparation among teachers currently teaching mathematics (Ingersoll, 1999). This is a factor that underlies another significant problem--that is, the lack of leadership to generate change. The stories of these three very different teachers underscore the harsh reality that efforts to promote improvements in math education programs will not succeed unless they are coupled with opportunities that target teachers' needs to grow as professionals. Their experiences suggest what is needed to expand the number of teacher leaders in mathematics.

In looking across the stories of these three teacher leaders, we find that while they share some qualities, their levels of content, pedagogical and/or leadership expertise set them apart. These differences reflect the diversity of the experiences they have encountered in their professional development journeys. First, we closely examine key features of these three stories. Then we offer recommendations to guide the planning and implementation of the type of professional development program needed to promote leadership among teachers of mathematics.

Rachel, Amber and Vickie, and most other teacher leaders we have observed, all share a strong commitment to raising the level of student achievement in mathematics. They strive to achieve this goal by making personal changes and improvements they feel will positively impact the quality of their teaching. Amber, for example, invested her own time to learn from a more experienced teacher because she lacked pedagogical skills as evidenced in her struggles with classroom management. Similarly, Vickie and Rachel spent considerable energy seeking out staff development to expand their mathematics knowledge base. All three have shown the courage needed to critically evaluate their teaching, and a willingness to invest time and effort in strengthening their weaknesses.

We also found that development of expertise as teachers and teacher leaders is gradual, and are most effective when supported by district leadership and continuous professional development. Rachel, who is by all accounts an exceptional teacher leader, benefited from both an encouraging administrator and at least five years of diverse, high-quality opportunities for professional enhancement. Vickie and Amber's experiences, however, were quite different, and probably typify what most mathematics teachers who take on leadership roles encounter. Both teacher leaders work in districts where the type of professional development needed to help them grow as teacher leaders has been extremely limited. They have found themselves, for the most part, taking their own initiative for their professional training. While they are taking responsibility for their own learning and improvement, the result is that the opportunities for staff development they have been able to access lacked coherence and depth, and have not included the follow-up that is needed to sustain change. Furthermore, these opportunities have not promoted the development of expertise that is key to effective leadership.

Rachel grew significantly as a result of the collaborative arrangements that were created through the programs in which she participated. Neither Vickie nor Amber, however, have had access to the kind of staff development that establish the professional networks needed to promote the collegiality and support for experimentation needed to help bring about change. In the absence of district support, dealing with this shortcoming will require determination on the part of these two teachers to gain access to programs that provide ongoing support from peers and critical friends. In their endeavors as department chairs, both Vickie and Amber are also working to address this need. Hopefully they understand this approach involves the phenomenal challenge of having to create a change their department members beliefs, knowledge and practice.

Both Vickie and Amber fell into leadership roles without the benefit of any leadership training. Rachel, on the other hand, did experience a professional development experience that integrated research on adult learning. Understanding the change process in adult learners helps teachers cope with their own issues and needs as they try to integrate change. It also helps teacher leaders grapple with the challenges in promoting change in colleagues. Without this type of leadership training, qualified and experienced mathematics teachers will struggle to become effective teacher leaders.

Interestingly, in contrast to the other eight teacher leaders, the mathematics teacher (Rachel and Amber) were the only teacher leaders in the study who did not identify a math teacher colleague as significant mentors their development as leaders. Vickie, who was involved in the study, also did not attribute her path to leadership to any collegial influence. Rather it was at the urging of a school administrator that Vickie accepted the task of heading up the math department. Rachel's initial foray into leadership was instigated by a couple of significant leaders, but they were also administrators and not exemplary math teachers. While in all cases we found that significant mentors were catalysts for steering these teachers on a path to leadership, in the case of mathematics this inducement did not come from a teacher leader or colleague. Math teachers were the only group that did not credit an influential teacher colleague as a mentor in their journeys, providing further evidence of the shortage of teacher leaders in mathematics.

Two of our teacher leaders, Rachel and Vickie, came to the realization that they did not know enough math to truly engage their students in meaningful mathematics discourse. Furthermore, they understood that they could become effective teachers of mathematics only if mathematics made sense to them and if they believed in their ability to make sense of it for their students. Once teachers see themselves as effective teachers to their students, they will have the confidence and credibility to serve as models and leaders to guide their peers. Once teaching, however, teachers have little access to opportunities to develop deep knowledge of mathematics. What is needed, therefore, is more in-depth, content-rich professional development, integrating subject matter knowledge with instructional strategies and assessment practices.

We have also observed that teachers who are supportive of local and national reform efforts tend to be teachers who know their content. In contrast, teachers who are resistant to reform efforts do not have the same high levels of content expertise, and continuously put up barriers to change that reflect this lack of expertise. For example, in a large urban school district where we have been working, one component of an assessment initiative required teachers to teach students about different kinds of patterns in the early elementary grades. This resulted in overwhelming criticisms

by teachers who perceived the study of patterns as a waste of instructional time. We discovered that very few teachers understood that the study of patterns laid the foundation needed for the study of functions in later grades. Similarly, two other performance assessments, one that targeted the relationship between perimeter and area and another that required an understanding of linear functions, were quickly denounced as being inappropriate and too difficult. Upon closer investigation we found that a key factor underlying the complaints was teachers' concerns about providing instruction in content they did not comprehend well enough to teach.

In the teacher profession, where demands are constantly changing and expanding, continued opportunities to learn are critical. Professional development can be an effective tool for promoting improvements in teaching (e.g., Wallace, Cederberg, & Allen, 1994). Furthermore, teachers report that professional learning opportunities are essential in helping them meet the demands of teaching (National Center for Educational Statistics, 1999b). The stories of these three teacher leaders demonstrate that the type of professional learning that facilitates growth simultaneously integrates professional collaboration with the development of teachers' pedagogical expertise, mathematical power, and leadership skills. Unfortunately, this broader conception of professional development does not currently characterize most on-going training opportunities available to teachers of mathematics (Cohen & Hill, 1998). By and large, what is missing is professional development that is coherent and focused on raising the level of mathematics content knowledge for teachers.

Conclusion

There is no question that making improvements in the math achievement of American students will only become a reality if changes take place in what in the quality of teaching in American classrooms. Change, however, is difficult, perhaps even more difficult than we think, because this means breaking away from what is considered to be a traditional cultural style of teaching (Stigler & Hiebert, 1999). Change will also take time as those teachers currently teaching math, just like the rest of us, hold perceptions of mathematics that were shaped by the way we were taught mathematics.

Clearly, it will take substantial investments to effect the changes needed to better prepare our teachers and teacher leaders. While no magical formula exists for "creating" the teacher leaders that are needed to drive new approaches to teaching mathematics, this work can be facilitated if districts and schools identify exemplary practicing teachers and support them through quality professional development that includes the components described above. That is, professional development characterized by the unique combination of quality, collaborative learning experiences that integrate pedagogical skills, assessment tools, and leadership skills, and above all, content knowledge.

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